C. Critique of Resource Services

We find the SUMEX-AIM network very well human engineered and the staff very friendly and helpful. The SECS project is probably one of the few on the AIM network which must depend exclusively on remote computers, and we have been able to work rather effectively via SUMEX. Basically we have found that SUMEX-AIM provides a productive and scientifically stimulating environment and we are thankful that we are able to access the resource and participate in its activities. SUMEX-AIM gives us at UCSC, a small university, the advantages of a larger group of colleagues, and interaction with people all over the country. We especially thank SUMEX for support of the leased line for our GT40.

D. Collaborations and Medical Use of Programs via Computers other than SUMEX

Arrangements between the University of California, Santa Cruz and NIH have been begun to try to install a version of SECS on the NIH PDP-10 computer system, and possibly later on the NIH-CIS system. Under an arrangement approved in 1974 between First Data, Princeton University, and NIH, SECS has been available over TELENET so that the public could evaluate the state of the technology first hand, by simply contacting First Data. First Data was selected because that is the system the NIH PROPHET program is also on. As a result of that arrangement, anyone who wishes can use the SECS program without worrying about converting code for their machine, and a number of people in the private sector both in the US and abroad have done so. Beryl Dominy of Pfizer wrote a paper about his experiences with the system.

The AIM-Executive committee has details of all developmental efforts on SECS in the United States and abroad as well as the plans for export of the SECS program. The University of California is handling arrangements for pre-release of the SECS program and will also handle final release of SECS, and is assuring that no conflicts of interest arise according to the NIH and University of California policies.

III. RESEARCH PLANS (8/78-7/81)

A. Long Range Project Goals and Plans

The SECS project now consists of two major efforts, computer synthesis and metabolism, the latter being a very young project. The SECS program with automatic FGI's and strategic controls that are now nearly useable represents a version which we feel will be satisfactory for distribution. Consequently, considerable effort over the next year will be toward that goal. We plan to continue exploring new aspects of the computer synthesis problem, such as depth first analysis, forward simulation of synthesis, and bidirectional search from target to key intermediate. There are many high level strategies of synthesis to be represented. The explanation capability, starting material libraries and starting material strategies, etc, are important features to be included. We have many ideas on how the current model builder could be made more general, faster, and more useful. A rewritten, smaller version of SECS which had an excellent TTY input and output module would be useful for possible installation on the NIH-CIS system where memory and cpu time are very critical to users.

The XENO metabolism project will be expanding the data base to cover more metabolic transforms, including species differences, sequences of transforms, and stereochemical specificities of enzymatic systems. A second phase will apply our "similarity" function to determine when metabolites are similar to known carcinogens. We are also hoping to develop programs which will help maintain the growing data bases. It is not clear at this time how quantitative we can hope to be with XENO's predictions and that will be studied.

Considerable development must occur to fully utilize the capabilities of the new GT46, including file transfer, and improvements to the graphics monitor to allow more local computations on the GT46 and GT40. We intend to keep the SECS program compatible with the entire GT40 family of terminals as it now is. We will be working on various types of hardcopy output, for the synthesis tree, sequences of reactions, the contents of libraries, and possibly even chemical transforms. In the next year we expect to see the SECS program used by more academic researchers over SUMEX than previously and they will need ways to obtain hardcopy of their results.

B. Justification and Requirements for Continued use of SUMEX

The SECS and XENO projects require a large interactive time-sharing capability with high level languages and support programs. I am on the campus computing advisory committee and know that the UCSC campus is not likely in the future to be able to provide this kind of resource. Further there does not appear to be in the offing anywhere in the UC system a computer which would be able to offer the capabilities we need. Thus from a practical standpoint, the SECS and XENO projects still need access to SUMEX for survival. Scientifically, interaction with the SUMEX community is still extremely important to my research, and will continue to be so because of the direction and orientation of our projects. Collaborations on the metabolism project and the synthesis project need the networking capability of SUMEX-AIM, for we are and will continue to be interacting with synthetic chemists at distant sites and metabolism experts at the National Cancer Institute. Our requirements are for good support of FORTRAN compiler and linker, particularly the capability to overlay our programs even on TENEX because in the outside community there is a need to overlay and we want to be able to assure that our program structure is overlayable, and in fact, we must soon overlay SECS on TENEX. Currently there is a bug in the loader which requires one to patch the SAV file every time one loads the program. We will also need ports into SUMEX since we will be using leased lines rather than TYMNET unless TYMNET installs a node in Santa Cruz.

We still are hopeful that someday there will be a good file transfer between TENEX and DECSYSTEM-10 machines via magnetic tape. That is still a difficult problem for anyone who is communicating with the outside world via tape.

C. Needs beyond SUMEX-AIM

Our needs are basically to be able to get local printing and solve the magtape file problems since we envision having to send out a great number of tapes to interested users.

D. Recommendations for community and resource development

The AIM workshop is excellent, particularly if it is held on the WEST COAST once in a while. From a chemistry standpoint, the joint group meetings with the DENDRAL group plus ability to attend seminars at Stanford really satisfy our needs for communication with people of similar interests. We have proposed a workshop for the benefit of the implementors rather than the principal investigators and administrators, for that would do wonders to develop the human resource. We feel the computer resource is rather efficiently used right now. At some point it may make sense to have a chemically oriented system as those applications develop.

4.1.3 HIGHER MENTAL FUNCTIONS PROJECT

MODELING OF HIGHER MENTAL FUNCTIONS

Kenneth Mark Colby, M.D.
Professor of Psychiatry, Biobehavioral
Sciences and Computer Science
University of California at Los Angeles

I. Summary of Research Program

A. Technical Goals:

The goals of this project lie in three areas of research:

(1) Improvement of and experimentation with a computer simulation of paranoid processes (PARRY). Little is known about the optimal treatment of paranoid conditions in psychiatry. Experiments with the model lead to specific recommendations for the communicative therapy of paranoid states and reactions.

(2) The development of a new psychiatric taxonomy for incapacitating neuroses of adulthood. The current classification scheme in this area is full of uncertainties and unreliabilities. A more reliable taxonomy would permit specific treatment interventions to be applied to more homogeneous groups of patients.

(3) The construction and development of an intelligent speech prosthesis for patients with language disorders, especially those who have suffered a stroke. Stroke is a double disaster because the patient not only suffers a serious illness but also may be unable to communicate with anyone about it or about himself. An intelligent speech prosthesis would provide a means of restoring spoken communication between the patient and those around him.

B. Medical Relevance and Collaboration:

This project is located in the UCLA Neuropsychiatric Institute. The problems of paranoia, psychiatric classification and language disorders secondary to stroke are of obvious medical relevance. The project members collaborate with a large number of psychiatrists, psychologists, neurolinguists and computer scientists working in biobehavior and medical fields.

C. Progress Summary:

In the past year we have developed an improved version of the paranoid model which now "thinks" by itself and treats input as an interrupt condition. The major improvement lies in its ability to keep better track of the conversation.

In establishing a Clinical Mental Health Research Center at UCLA we have been collaborating with seven other investigators in psychiatry, ethology, electrophysiology, psychophysiology, neuropsychology, psychology and statistics in an effort to construct a new taxonomy for the severe neuroses. This population, while large (10-15% of the total U.S. population), has been little studied and hence is little understood. A reliable taxonomy must be developed as a first step. We are studying these patients from a number of perspectives. The Higher Mental Functions project contributes a cognitive assessment of the patient which attempts to categorize him in terms of his concepts and key ideas. We are just beginning to collect this data and correlating it with data from other assessments. The Principal Investigator of this project is also the PI and Director of the Clinical Mental Health Research Center.

The intelligent speech prosthesis now has about 800 orthographic-to-phonetic rules which give it an infinite vocabulary. We have constructed an ear-button allowing the user to correct errors through auditory as well as visual feedback. We have drawn the schematics for a portable device which can be worn on the arm and are in the process of building this portable device. Also we have begun to construct a dynamic associative network which aids the user in word-finding. This type of semantic and phonetic memory will become unique to the user over time because the device keeps track of which associations are used more often in word-searching.

D. List of Relevant Publications:

Parkison, R. C., Colby, K. M. and Faught, W. S. Conversational Language Comprehension Using Integrated Pattern-Matching and Parsing. ARTIFICIAL INTELLIGENCE, 9, 111-134, 1977.

Colby, K. M. On the Way People and Models Do It. PERSPECTIVES IN BIOLOGY AND MEDICINE, 21, 99-104, 1977.

Colby, K. M., Christinaz, D., Parkison, R. C. and Faught, W. S. A Proposed Psychiatric Taxonomy Based On the Conceptual Patterns and Key Ideas in Patient Accounts. ALGORITHMIC LABORATORY OF HIGHER MENTAL FUNCTIONS PROJECT, MEMO ALHMF-10, 1977. UCLA Department of Psychiatry. Colby, K. M. Mind Models: An Overview of Current Work. MATHEMATICAL BIOSCIENCES, In Press, 1978.

Colby, K. M., Christinaz, D. and Graham, S. A. A Computer-Driven, Personal, Portable, and Intelligent Speech Prosthesis. COMPUTERS AND BIOMEDICAL RESEARCH, June, 1978.

E. Funding Support Status:

This project is funded entirely by intradepartmental funds from the Biobehavioral Sciences Program. No other contracts or grants are at present involved. Applications for grants have been made to the National Institute of Mental Health, the National Science Foundation and the National Institute of Neurological and Communicative Disorders and Stroke.

II. Interactions with the SUMEX-AIM Resource

A. Collaborations

We have collaborated with Professor Jon Heiser, Department of Psychiatry, University of California, Irvine in testing the paranoid model. Also we have consulted with Professor John Eulenberg, Department of Computer Science, Michigan State University, regarding problems of intelligent artificial speech. Many informal consultations also take place with other SUMEX users regarding specific problems.

B. Sharing:

Members of the project participate in the Rutgers AIM workshops and in other conferences which SUMEX users also attend.

C. Criticism:

We have no criticism of SUMEX itself. It is easily the best system we have ever used. Our only criticism is directed at TYMNET which is so unreliable (garbling characters) as to be practically unusable.

III. Research Plans

A. Long Range Goals:

We plan to continue to work on the problems of paranoid conditions, psychiatric taxonomy, and intelligent speech prosthesis over the next three years at least.

B. Justification for Continued SUMEX Use:

Without SUMEX this project could not continue its work on paranoia and on psychiatric taxonomy. Both of these efforts involve large LISP programs which must be run interactively on a large time-shared system. Work on intelligent artificial speech requires use of large dictionaries such as available on SUMEX. We do not anticipate requiring any further space allocations than we now have.

C. Other Computational Resources:

We use microprocessors and a 360/91 at UCLA in addition to SUMEX in the research on intelligent artificial speech.

D. Recommendations:

We strongly recommend that the SUMEX-AIM facility be continued. Otherwise we would not be able to continue the bulk of our research efforts.

4.1.4 INTERNIST PROJECT

INTERNIST - Diagnostic Logic Project

J. Myers, M.D. and H. Pople, Ph.D.
University of Pittsburgh

I. SUMMARY OF RESEARCH PROGRAM

A. Technical Goals

The major goal of the INTERNIST project is to produce a reliable and adequately complete diagnostic consultative program in the field of internal medicine. Although this consultative program is designed primarily to aid skilled internists in complicated medical problems, the program may have spin-off as a diagnostic and triage aid to physicians assistants, rural health clinics, military medicine and space travel.

To be effective, the program must be capable of multiple diagnoses (related or independent) in a given patient and it should deal effectively with the time axis in the development and course of disease states.

B. Medical Relevance and Collaboration

The program inherently has direct and substantial medical relevance.

The knowledge base should reach a critical stage of completeness within a year to 18 months, at which point we shall invite collaboration in the field testing of the program in a number of medical institutions. Desires for such collaboration have been very positively indicated by more than an adequate number of sister academic health centers and community hospitals, etc.

The Department of Pediatrics at Pittsburgh has just begun a collaboration with INTERNIST with the objective of a similar diagnostic program in the field of pediatrics.

C. Progress Summary

The original INTERNIST program described in previous progress reports and documented in Pople, Myers & Miller [3] continues to be the standard diagnostic program used to analyze clinical problems and to exercise newly developed portions of the knowledge base.

The structure of the medical knowledge base has remained comparatively constant during the past year. The knowledge base has been expanded by the addition of some fifty diseases. The existing knowledge base is under a process of continual editing which attempts to keep the data up to date by the addition of new information about diseases as such becomes available, and which expands

and corrects the old data base as omissions or errors are discovered. To our gratification, the progressive enlargement of the knowledge base has in no significant adverse way affected the operation of the computer program.

The program and the knowledge base are continually being tested with challenging medical problems with good and reasonable success. The knowledge base remains too incomplete for any comprehensive or critical test on our hospital floors but the system is used on an ad hoc basis for clinical guidance.

Experience with this system has led to the identification of certain performance deficiencies that are being addressed in the design of a second generation diagnostic program (INTERNIST-II) the essential features of which are outlined in Pople [1]. A major objective in the design of the new program is to enable concurrent evaluation of the multiple components of a complex clinical problem, thereby enhancing the system's rate of convergence on the essential nature of the problem. A number of new concepts, not presently captured in the existing INTERNIST knowledge base, are required for this purpose; for example: the "constrictor" relation described in [1]; generalization of the INTERNIST disease hierarchy to a network permitting multiple categorization, and incorporation of "temporal schemata" used to permit expression of the time course of disease processes. The detailed design of these data structures and the diagnostic procedures that use them has progressed to the point of preliminary testing, but it should be emphasized that this is a research area in which considerable work remains to be done.

Two full-time graduate students in computer science and two full-time clinical fellows in medicine will be working on the INTERNIST project in 1978-79. This constitutes our largest training staff to date and these young persons will undoubtedly contribute significantly to the speed and quality of the project's continuing development.

D. Publications

1. Pople, H.E. "The Formation of Composite Hypotheses in Diagnostic Problem Solving: An Exercise in Synthetic Reasoning", Proceedings of the Fifth International Joint Conference on Artificial Intelligence, Boston, August 1977.

2. Pople, H.E. "On the Knowledge Acquisition Process in Applied A.I. Systems", Report of Panel on Applications of A.I., Proceedings of Fifth International Joint Conference on Artificial Intelligence, 1977.

3. Pople, H.E., Myers, J.D. & Miller, R.A. "The DIALOG Model of Diagnostic Logic and its Use in Internal Medicine, Proceedings of the Fourth International Joint Conference on Artificial Intelligence, Tbilisi, USSR, September 1975.

4. Pople, H.E. "Artificial-Intelligence Approaches to Computer-based Medical Consultation, Proceeding IEEE Intercon, New York, 1975.

E. Funding Support Status

1. Title of Grants:
   (a) Dialog: A Computer Model of Diagnostic Logic
   (b) Clinical Decision Systems Research Resource

2. Principal Investigators:
   (a) Jack D. Myers, M.D. University of Pittsburgh
       Harry E. Pople, Ph.D. University of Pittsburgh
   (b) Jack D. Myers, M.D. University of Pittsburgh
       Harry E. Pople, Ph.D. University of Pittsburgh

3. Funding Agencies:
   (a) BHRD
   (b) NIH

4. Grant or Contract Identification number:
   (a) 5R01 MB00144 04 (total period 7/74 - 6/78)
   (b) 1R24 RR01101 01 (total period 7/77 - 6/80)

5. Current Terms:
   (a) 6/30/77-6/29/78
       $101,000 (direct costs)
   (b) 7/1/77-6/30/78
       $160,000 (direct costs)

II. INTERACTIONS WITH SUMEX-AIM RESOURCE

A,B. Collaborations and Medical Use of Program Via SUMEX

INTERNIST remains in a stage of research and development. As noted in the "Progress Summary" above, we are continuing to attempt to develop better computer programs to operate the diagnostic system, and the knowledge base cannot be used very effectively for collaborative purposes until it has reached a critical stage of completion. These factors have stifled collaboration via SUMEX up to this point and will continue to do so for the next year or two. In the meanwhile, through the SUMEX community there continues to be an exchange of information and states of progress. Such interactions particularly take place at the annual AIM Workshop.

Dr. Victor Yu, formerly associated with MYCIN, is now a faculty member at the University of Pittsburgh and has begun active participation in INTERNIST. Dr. Yu will be particularly valuable in the programming of infectious diseases.

C. Critique of Resource Management

SUMEX has been an excellent resource for the development of INTERNIST. Our large program is handled efficiently, effectively and accurately. The staff at SUMEX have been uniformly supportive, cooperative, and innovative in connection with our project's needs.

III. RESEARCH PLANS (8/78 TO 7/81)

A. Long Range Project Goals and Plans

The primary goal of INTERNIST is to develop and complete an effective and reliable instrument for diagnostic consultation in internal medicine. To accomplish this a very extensive knowledge base must be developed, tested and continually updated. The initial stage of development is about 75% accomplished; a reasonable complete knowledge base, incorporating the new data structures identified in section I above, is a year to 18 months in the future. With this development together with the improvement in the computer analytical program, INTERNIST will be suitable for a critical field trial, first in our own health center and, assuming success, in a half-dozen or so of additional health care institutions. Successful completion of the field test should make the program ready for practical clinical use.

B. Justification and Requirements for SUMEX Use

Neither the continued evaluation and development of INTERNIST's computer program nor the manipulation and further development of INTERNIST's knowledge base can be accomplished without a large computer resource such as SUMEX. SUMEX has thus far met our requirements admirably and those requirements for the research and development component of INTERNIST should remain relatively constant over the next three years. The SUMEX resource (or its equivalent) is absolutely essential to INTERNIST's progress.

C. Needs and Plans for Other Computational Resources

As predicted above, INTERNIST should be ready for field testing within two years. It is realized that it is not the purpose to SUMEX in its present form to support such extensive trials. Accordingly, a dedicated computer (or a dedicated portion of SUMEX) will be needed to carry out the trials. No specific plans have yet been made for this operation.

4.1.5 MEDICAL INFORMATION SYSTEMS LABORATORY

MISL - Medical Information Systems Laboratory

M. Goldberg, M.D. and B. McCormick, Ph.D.
University of Illinois at Chicago Circle

I) SUMMARY OF RESEARCH PROGRAM

A) TECHNICAL GOALS

The Medical Information Systems Laboratory (MISL) was established under grant HM-0114 in Chicago to pursue three activities: i) Construction of a database in ophthalmology, ii) Clinical knowledge system support, and iii) Network-compatible database design. Priorities in year 04 of MISL's operation are the same as in previous years: investigations into how to construct a database in ophthalmology, and into distributed database design, are ancillary to the exploration of a clinical knowledge system to support clinical decision making. We are developing ways to get reliable clinical information into the ophthalmic database primarily because we are interested in getting out significant clinical decision support.

B) APPROACH AND MEDICAL RELEVANCE

B.1) Construction of the database in Ophthalmology

A specific aim of this project is to construct a workable database in ophthalmology, using the outpatient population of the Illinois Eye and Ear Infirmary. We view this database as a testbed for developing clinical decision support systems. The Ophthalmology Department of the Illinois Eye and Ear Infirmary provides an excellent environment for evaluating new techniques for capturing and using clinical information.

B.2) Clinical knowledge support system

The goals for clinical knowledge system development are to provide a flexible user interface for a prototype relational database system, to devise means of accessing alphanumeric and pictorial information stored in the database system, and to provide efficient means for logically restructuring a database so that it can be adapted to different operating environments in a network-compatible distributed medical information network.

C) PROGRESS SUMMARY (INCLUDING ITEMS OF INTEREST TO SUMEX-AIM COMMUNITY ONLY)

C.1) The database in ophthalmology

Since last year, the clinical support computer system has been relocated to the Goldberg Research Center, across a street from the Illinois Eye and Ear Infirmary at the University of Illinois Medical Center Campus. Physician terminals and interfaces to ophthalmic instruments have been positioned in the general eye clinic of several key ophthalmic subspecialty clinics. Systematic, modular hardware and software for clinical source data acquisition have been established. The hardware configuration and telecommunication linkages have stabilized. We are presently using RAIN, a relational database system developed by Prof. S. K. Chang of MISL, to collect general eye index data, along with data about glaucoma.

C.2) Clinical knowledge system support

C.2.a) Development of the relational database includes the following:

- A user interface through which unsophisticated users communicate with the database.

- An intelligent coupler that serves as an intermediary between the end user and the distributed database system. The coupler listens to the user's retrieval requests; helps the user formulate his requests correctly; efficiently translates user's retrieval requests into a network-compatible retrieval command language; and obtains authorization from the system for data retrieval and/or update.

- Tools for picture data management. Graphical indexing techniques are provided so that the clinical researcher and physician can easily retrieve pictorial/graphical information from the medical database.

- Means for logical database synthesis. This involves conversion of the user's view of the database into a logically coherent physical organization.

C.2.b) Development of a computer-based consultation system for diagnosis and management of glaucoma. This involves ongoing collaboration between Dr. Jacob Wilensky at MISL, and, through SUMEX-AIM, other investigators around the United States. Included are the original investigators in glaucoma consultation: Dr. Casimir Kulikowski (Rutgers), Dr. Shalom Weiss (Mt. Sinai Hospital, NY), and Dr. Aaron Safir (Mt. Sinai Hospital).

C.2.c) Prof. Brian Phillips has used SUMEX-AIM during the last year to implement a model of knowledge, called an encyclopedia. Implemented in INTERLISP, the model includes a network representation for procedures, similar in spirit to the representation in Earl Sacerdoti's "Structure for plans and behavior". Prof. Phillips will discuss his work at an AI conference in Europe early this summer.

C.2.d) Formal models for consultation systems. Petri nets have been studied, primarily be Murata (see below), as a formal representation for interacting parallel processes. Petri nets are similar to causal networks, as described by Kulikowski and Weiss at Rutgers, except that, with Petri nets, cyclic activity is easily represented. The similarity between Petri nets and inference nets has also been noted (Walser and McCormick). The utility of the Petri net framework for modelling physical processes was explored by Walser, with the construction of a simulated coffee maker. Further studies are planned.

D.) LIST OF MISL PUBLICATIONS

Chang S. K., "Intelligent coupling of the user to medical information systems", PROCEEDINGS OF THE THIRD ILLINOIS CONFERENCE ON MEDICAL INFORMATION SYSTEMS, November 4-6, 1976, Chicago, Illinois.

Chang S. K., "A model for distributed computer systems design", IEEE TRANSACTIONS ON SYSTEMS, MAN, AND CYBERNETICS, SMC-6, no. 5, May 1976, pp. 344-359.

Chang S. K. and Cheng W. H., "Database skeleton and its application to logical database synthesis", IEEE TRANSACTIONS ON SOFTWARE ENGINEERING, vol SE-4, no. 1, 1978, pp. 18-30.

Chang S. K. and Ke J. S., "Database skeleton and its application to fuzzy query translation", IEEE TRANSACTIONS ON SOFTWARE ENGINEERING, vol SE-4, no. 1, 1978, pp. 31-44.

Chang S. K., Donato N., McCormick B. H., Reuss J. and Rocchetti R., "A relational database system for pictures", PROCEEDINGS IEEE COMPUTER SOCIETY WORKSHOP ON PICTURE DATA DESCRIPTION AND MANAGEMENT, Chicago, Illinois, April 1977.

Church R. W. and Murata T. "Properties of a modified incidence matrix for computation graphs", PROCEEDINGS OF THE 1977 ALLERTON CONFERENCE ON COMMUNICATION, CONTROL, AND COMPUTING, September 1977.

Manacher G. K., "An improved version of the Cocke-Younger-Kasami Algorithm", to be published in J. OF COMPUTER LANGUAGES, 14 pages.

Manacher G. K., "An application of pattern matching to a problem in geometrical complexity", INFORMATION PROCESSING LETTERS, vol. 5, no. 1, 1976, pp. 6-7.

McCormick B. H., Chang S. K., Borovec R. T., Read J. S. and Wilensky J. T., "Technological trends in clinical information systems", MEDINFO 77, Shires and Wolf (Editors), North Holland Publishing Company, 1977, pp. 43-48.

McCormick B. H. and Amendola, R. C., "Cytospectrometers for subcellular particles and macromolecules: design considerations", Workshop on THEORY, DESIGN AND BIOMEDICAL APPLICATIONS OF SOLID STATE CHEMICAL SENSORS, Case Western Reserve University, March 28-30, 1977.

McCormick B. H., Read J. S., Borovec R. T., Amendola R. C., and Goldbaum M. H., "Image processing in Television Ophthalmoscopy", in DIGITAL PROCESSING OF BIOMEDICAL IMAGES, K. Preston and M. Onoe (Editors), Plenum Press, 1976, pp. 399-424.

Murata T., "State equations for E-Net interpreted marked graphs", PROCEEDINGS OF THE 19th MIDWEST SYMPOSIUM ON CIRCUITS AND SYSTEMS, August 1976, pp. 152-157.

Murata T. and Shah T., "on liveness, deadlock, and reachability of E-Nets", PROCEEDINGS OF THE 14th ALLERTON CONFERENCE ON CIRCUIT AND SYSTEM THEORY, October 1976, pp. 597-605.

Murata T., "A method for synthesizing marked graphs from given markings", PROCEEDINGS OF THE 10th ASILOMAR CONFERENCE ON CIRCUITS, SYSTEMS, AND COMPUTERS, November 1976, pp. 202-206.

Murata T., "State equations, controllability and maximal matchings of Petri nets", IEEE TRANSACTIONS ON AUTOMATIC CONTROL, vol. AC-22, No. 3, June 1977, pp. 412-416.

Murata T., "Petri nets, marked graphs, and circuit system theory - a recent CAS application", CIRCUITS AND SYSTEMS, vol. 11, no. 3, June 1977, pp. 2-12.

Murata T., "Circuit theoretic analysis and synthesis of marked graphs", IEEE TRANSACTIONS ON CIRCUITS AND SYSTEMS, vol. CAS-24, no. 7, July 1977.

Murata T. and Onaga K. "Deadlock in capacitied computation networks", PROCEEDINGS OF THE 20th MIDWEST SYMPOSIUM ON CIRCUITS AND SYSTEMS, August 1977.

Murata T. and Onaga K., "Marked graphs with token capacity constraint", IEEE TRANSACTIONS ON CIRCUITS, SYSTEMS, AND COMPUTERS, November 1977.

Murata T., Onaga K., and Tani K., "Maximum firing number in capacited marked graphs", PROCEEDINGS OF THE 1977 ASILOMAR CONFERENCE ON CIRCUITS, SYSTEMS, AND COMPUTERS, November 1977.

Nordmann B. H. and McCormick B. H., "Modular asynchronous control design", IEEE TRANSACTIONS ON COMPUTERS, March 1977.

Tani T., Onaga K. and Murata T., "Termination conditions for capacited computation graphs", PROCEEDINGS OF THE 1977 JAPAN NATIONAL CONFERENCE ON INFORMATION PROCESSING, August 1977.

Walser R. L., Hain T. and McCormick B. H., "Design of a relational database system for pathology", To appear in PROCEEDINGS OF THE FOURTH ILLINOIS CONFERENCE ON MEDICAL INFORMATION SYSTEMS, Urbana, Illinois, May 10-12, 1978.

Walser R. L., McCormick B. H., Chang S. K., Ruppel J., and Wilensky J. T., "Applications of an ophthalmic information system", To appear in PROCEEDINGS OF THE WORKSHOP ON COMPUTER LABORATORY HEALTH CARE RESOURCES PROGRAM, January 11-13th, 1978, Lubbock, Texas.

Walser R. L. and McCormick B. H., "A system for priming a clinical knowledge base", PROCEEDINGS OF THE NATIONAL COMPUTER CONFERENCE, June 1977, Dallas, Texas, pp. 171-177.

Walser R. L. and McCormick B. H., "Organization of clinical knowledge in MEDICO", PROCEEDINGS OF THE THIRD ILLINOIS CONFERENCE ON MEDICAL INFORMATION SYSTEMS, Chicago, Illinois, November 4-6, 1976.

Wilensky J. T., "Intraocular lenses", in OPHTHALMOLOGY: PRINCIPLES AND MANAGEMENT, G. Peyman, D. Sanders, and M. F. Goldberg (Editors), in preparation.

Wilensky J. T., "Current concepts in primary angle-closure glaucoma", ANN. OPHTHALMOL., August 1977, pp. 963-972.

Wilensky J. T., Goldberg M. F. and Alward P., "Glaucoma after pars plana vitrectomy", TRANS. AM. ACAD. OPHTHALMOL. OTOLARYNGOL., vol. 83, Jan.-Feb. 1977, pp. 114-121.

E.) FUNDING STATUS

1. Title: Medical Information Systems Laboratory
2. Principal Investigators: B. H. McCormick and M. F. Goldberg
3. Agency: PHS, Department of Health Manpower
4. Id number: PHS-MB00114

5. & 6. Current terms:
This year (7/77 - 6/78) $222,487
MISL funding ends 6-29-78. MISL will retain its identity however, and much of the work begun under MISL will continue. Many of the individuals who formerly worked under MISL will continue on database projects under ARPA funding.

II) INTERACTION WITH SUMEX-AIM RESOURCE

A.) COLLABORATION

Major collaboration at present is through the ONET, involving the ophthalmology departments of five medical schools. Dr. Jacob Wilensky is actively engaged in evaluating and modifying the Glaucoma Consultation Program, written originally by Shalom Weiss.

B.) CRITIQUE OF RESOURCE SERVICES

Users at MISL are pleased with SUMEX-AIM services. The availability of up-to-date online documentation makes it easy to learn how to use the system and stay abreast of new developments. The online bulletin board is especially commendable. Since documentation is so readily available, consultation with SUMEX staff has rarely been necessary.

III) FOLLOW-ON SUMEX GRANT PERIOD

A.) LONG RANGE USER PROJECTS AND GOALS

One of MISL's accomplishments is the establishment of an information system for the Illinois Eye and Ear Infirmary (IEEI). After MISL funding terminates in June, 1978, the IEEI will continue to use MISL facilities, mainly for clinical databases and text editing in clinical offices. In July (under ARPA funding), several MISL personnel are slated to begin development of an augmented version of RAIN, the relational database system developed under MISL. This new system will form the basis for a relational database in pathology, which will serve both the Illinois Eye and Ear Infirmary and the pathology department at the University of Illinois Hospital.

B.) JUSTIFICATION FOR CONTINUED USE OF SUMEX

Access by our staff to SUMEX facilities and opportunity for inter-institutional collaboration have been enhanced by a SUMEX (PDP-10) - MISL (PDP-11) phone connection, which has been operational since last summer.

One of MISL's original goals was network-compatible database design. We have recently taken a large step toward that goal with the implementation of a special network version of the Unix operating system for our PDP-11 minicomputers. We presently have a network of five minicomputers, including various databases, on the University of Illinois Circle and Medical Center campuses. We have been collecting glaucoma and general eye index data for some time, and will soon create a large pathology database. We feel that we are in an especially good position to experiment with the sharing of data through computer networks. Especially interesting is the sharing of data between very remote sites, using phone lines. Our link to SUMEX-AIM provides a perfect outlet for our distributed database plans.

It is worth noting that several MISL personnel, including Prof. S. K. Chang, R. L. Walser, A. C. Petersen, and H. Dreizen, will continue to work on distributed database problems. The work will continue under the Distributed Image Management And Projection project (DIMAP), funded by ARPA. While the former MISL personnel will take on new obligations, they will most certainly continue to interact with physicians at the Illinois Eye and Ear Infirmary. It is planned that much of the DIMAP research will take place on the former MISL computer system; the DIMAP group has agreed to maintain the Unix operating system in exchange for free access to the computer system.

SUMEX-AIM is presently being used extensively by Prof. Brian Phillips and his students. Using INTERLISP, Prof. Phillips is coding a model of knowledge developed over a period of years at the State University of New York at Buffalo, and later in the Department of Information Engineering and MISL in Chicago. While the model of knowledge is well-developed, and has been implemented at another site in SNOBOL, the INTERLISP version requires further work. Since Prof. Phillips has shifted his work entirely to SUMEX-AIM, he is quite anxious to keep his access privileges.

C.) SUGGESTIONS FOR FUTURE RESOURCE DEVELOPMENT EFFORTS

As mentioned above, we are very interested in coupling our PDP-11 based UNIX operating system with the SUMEX-AIM network. and would like to encourage similar connections at other sites. There are several advantages. Maintaining voluminous patient-related data on minicomputer systems would provide for local security, and help to keep SUMEX secondary storage free for service and development programs and documentation. The enhanced opportunity for inter-site collaboration and database sharing is obvious, and would be beneficial to the SUMEX-AIM community as a whole.

4.1.6 PUFF/VM PROJECT

PUFF/VM: Pulmonary Function and Ventilator Management Project

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The immediate goal of this project is the development of knowledge-based programs which interpret physiological measurements made in clinical medicine. The interpretations are intended to be used to aid in diagnostic decision making and in therapeutic actions. The programs will operate within medical domains which have well developed measurement technologies and reasonably well understood procedures for interpretation of measured results. The programs are:

(1) PUFF: the interpretation of standard pulmonary function laboratory data which include measured flows, lung volumes, pulmonary diffusion capacity and pulmonary mechanics, and

(2) VM: management of respiratory insufficiency in the intensive care unit.

The second, but equally important, goal of this project is the dissemination of Artificial Intelligence techniques and methodologies to medical communities that are involved in computer aided medical diagnosis and interpretation of patient data.

I. SUMMARY OF RESEARCH PROGRAM

PUFF

A. Technical Goals

The task of PUFF program is to interpret standard measures of pulmonary function. It is intended that PUFF produce a report for the patient record, explaining the clinical significance of measured test results. PUFF also must provide a diagnosis of the presence and severity of pulmonary disease in terms of measured data, referral diagnosis, and patient characteristics. The program must operate effectively over a wide range of pathological conditions with a broad clinical perspective about the possible complexity of the pathology.

B. Medical Relevance and Collaboration

Interpretation of standard pulmonary function tests involves attempting to identify the presence of obstructive airways disease (OAD: indicated by reduced flow rates during forced exhalation), restrictive lung disease (RLD: indicated by reduced lung volumes), and alveolar-capillary diffusion defect (DD: indicated by reduced diffusivity of inhaled CO into the blood). Obstruction and restriction may exist concurrently, and the presence of one mediates the severity of the other. Obstruction of several types can exist. In the laboratory at the Pacific Medical Center (PMC), about 50 parameters are calculated from measurement of lung volumes, flow rates, and diffusion capacity. In addition to these measurements, the physician may also consider patient history and referral diagnosis in interpreting the test results and diagnosing the presence and severity of pulmonary disease.

Currently PUFF contains a set of about 60 physiologically based interpretation "rules". Each rule is of the form "IF <condition> THEN <conclusion>". Each rule relates physiological measurements or states to a conclusion about the physiological significance of the measurement or state.

The interpretation system operates in a batch mode, accepting input data and printing a report for each patient. The report includes: (1) Interpretation of the physiological meaning of the test results, the limitation on the interpretation because of bad or missing data; the response to bronchodilators if used; and the consistency of the findings and referral diagnosis. (2) clinical findings, including the applicability of the use of bronchodilators, the consistency of multiple indications for airway obstruction, the relation between test results, patient characteristics and referral diagnosis. (3) Interpretation Summary, which consists of the diagnosis of presence and severity of abnormality of pulmonary function.

Initially the rules were proposed by our pulmonary physiologist during discussions with systems staff consisting of biomedical engineers from PMC and computer scientists from Stanford. The process of rule development involved iteratively refining the rules to make the rule interpretations arbitrarily close to the interpretation by the physiologist for a set of test cases. A set of 107 representative case results was selected from the files of our laboratory for retrospective analysis during rule development. Statistical analysis was used to characterize the consistency and information content of the retrospective data. Prospective analysis of 144 new cases then was used to evaluate the consistency of the interpretations by the physiologist in comparison with a second independent physiologist , and with the rules.

C. Progress Summary

Knowledge base:

PUFF is implemented on the PDP10 in a version of the MYCIN system which is designed to accept rules from new task domains. Currently approximately 60 pulmonary physiology rules related to the interpretation of measurements mentioned above have been implemented. A typical rule is:

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If (FVC(PP)>=80) and  (FEV1/FVC<predicted-5) then PEAK FLOW RATES ARE
REDUCED, SUGGESTING AIRWAY OBSTRUCTION OF DEGREE
        if (predicted-15<= FEV1/FVC <predicted-5) MILD
        if (predicted-25<=FEV1/FVC <predicted-15) MODERATE
        if (predicted-35<=FEV1/FVC <predicted-25) MODERATE TO SEVERE
        if (FEV1/FVC <predicted-35)               SEVERE
```

Results

A representative sample of 107 test cases was taken from the computer records of our pulmonary function laboratory. During the process of characterizing the data base statistically and developing the rule set for interpretation, the director of our pulmonary laboratory changed his diagnosis on 42 of the 107 cases. The largest number (14) of the changes in diagnosis was a change from an original diagnosis of Pulmonary Function "Within Wide Limits of Normal" to a diagnosis of obstruction or restriction of a mild degree. The original normal diagnosis was made either because he felt that the patient did not need to be confronted with an abnormal diagnosis, or because he knew the patient and made the diagnosis on background information rather than the measured data. The addition of diffusion defects or changes in degree were involved for nine patients. In five cases a mild restriction diagnosis was added for patients with OAD. Three data errors were found, and three OAD subtype changes were made. The majority of the remainder (14) of the changed diagnoses were changes of degree of severity by one degree, e.g. from mild to moderate. The changes in severity were made because, when he analyzed the data systematically, he came to a different conclusion than when individual cases were analyzed in isolation.

The results of a preliminary comparison we conducted to compare the interpretations made by PUFF and those made by the physiologists are summarized in Tables 1 and 2. Table 1 compares agreement in diagnoses made by the first MD-pulmonary physiologist with the second physiologist and with the PUFF rules. Comparison is made independent of the severity of condition reported in the diagnosis. The overall rate of agreement between the two physiologists on four diagnoses (Normal, OAD, RLD, DD) for 144 cases was 86%, and between the first physiologist and the rules 90%. There was substantially lower percentage of agreement in diagnosing OAD subtype (asthma, bronchitis, emphysema) than in diagnosing primary pulmonary abnormality.

Diagnosis (Dx)	Number With Dx	Number Without Dx	Percent Agreement With Diagnosis by 1st M.D. Second M.D.	PUFF Rules
Normal	31	113	0.91	0.93
OAD	79	65	0.86	0.88
RLD	52	92	0.92	0.94
DD	40	104	0.76	0.86
Asthma	15	64	0.81	0.84
Bronchitis	9	70	0.61	0.81
Emphysema	32	47	0.82	0.84

Table 1. Percentage agreement of diagnoses by a second MD-physiologist and by PUFF rules with a first MD-pulmonary physiologist. 144 cases were interpreted prospectively. Some abnormal cases had more than one pathological condition.

Table 2 compares agreement in severity of diagnoses made by the two MD's and by PUFF rules. In 94% of the 144 cases, the degree of severity (0=none; 1=mild; 2=moderate; 3=moderately-severe; 4=severe) of OAD diagnosed by the first MD was within a single degree of severity of OAD diagnosed by the second MD. In 96% of the 79 cases for which the first MD diagnosed OAD, the second MD diagnosed the severity of OAD within one level of the severity diagnosed by the first MD. Agreement within one degree of severity of the diagnoses by the first and second MD's was substantially lower in RLD and DD cases. These discrepancies occurred because the second MD consistently called RLD more severe than did the first MD, and he consistently did not diagnose diffusion defects when the first MD diagnosed DD of moderate or greater degree.

Diagnosis	Percent Agreement with 1st MD: All 144 cases Second M.D.	All 144 cases PUFF Rules	1st MD made Dx Second M.D.	1st MD made Dx PUFF Rules
Normal				
OAD	0.94	0.99	0.96	0.97
RLD	0.92	0.97	0.77	1.00
DD	0.87	0.87	0.60	0.80
Total	0.91	0.94	0.86	0.94

Table 2. Percent agreement within one degree of severity of diagnoses by two MD's and by the first MD and rules.

Tables 1 & 2 are taken from analysis of the same 144 cases.

VM

A. Technical Goals

The task of the VM program is to provide real-time consultative advice for patients undergoing mechanical ventilation in the intensive care unit at the Pacific Medical Center. This intensive care unit has an on-line computer based patient monitoring system which automatically obtains approximately twenty physiological parameters. VM is intended to be an extension of this system that will (1) provide a summary of the patient status easily understood by the clinician, (2) recognize untoward events and provide suggestions for corrective action, (3) advise on adjustment of a mechanical ventilator based on assessments of patient status and therapeutic goals, and (4) detect possible measurement errors.

The VM system is designed to be an expectation-driven system which utilizes the current and past history of the patient to establish guidelines for interpreting patient measurements. These guidelines, or expectations, are used to dynamically establish upper and lower limits for comparison with each measurement. Persistent patterns in the violations of these limits represent unexpected clinical situations that may require adjustment of the equipment or other actions by the physician..

The overall plan includes a telephone connection between the IBM 1800/PDP-11 patient monitoring system at PMC and the Sumex PDP-10. The ICU patient's physiological measurements will be provided on a 2-10 minute basis for analysis by the VM program. Summary information, suggestions to the clinicians, and/or requests for additional information will be sent back to the ICU for action.

B. Medical Relevance and Collaboration

The VM problem domain of interpretation in the dynamic ICU environment brings together the designers who created the current monitoring system with computer scientists experienced in medical interpretation (MYCIN) and signal understanding research [Shortliffe:76, Nii:77]. We are directing our attention to the assistance of clinicians in the management of patients who need ventilatory support. VM will offer advice on a wide range of clinical problems ranging from one-time decisions on the selection of an appropriate ventilator and the initial settings for the equipment to continuous monitoring of the patient. The main effort is directed toward the tracking of the patient physiological status while on the ventilator, and on providing suggestions for adjustments of the ventilator settings as necessary. This includes advice on the process of removing the patient from the ventilator. An up-to-date summary stated in terms of physiologically based conclusions rather than the individual measurements will also be provided.

To assist in the interpretation process, VM must be able to recognize unusual or unexpected clinical events (including machine malfunction) in a manner specifically tailored to the patient in question. The interpretation task is viewed as an ongoing process in the ICU, so that the physiological measurements must be continually reevaluated producing a current clinical picture.

This picture can then be compared with previous summary of patient status to recognize changes in patient condition upon which therapy selection and modifications can be made. The program must also determine when the measurements are most likely to be sensitive to error or when external measurements would be of diagnostic significance.

VM offers a new approach towards more accurate recognition of alarm conditions by utilizing the history and situation of the patient in the analysis. This is in contrast to the use of static limits applied to measurements generated to fit the "typical patient" under normal conditions. Our program uses a model of interpretation process, including the types and levels of conclusions drawn manually from the measurements to provide a summary of patient condition and trends. The program generated conclusions are stated at levels more abstract than the raw data; for example, the presence of hemodynamic stability/instability rather than in terms of heart rate and mean arterial pressure. When the data is not reliable enough to make these conclusions, additional test may be suggested. The recognition of important conclusion for which external verification is sought, will also elicit the suggestion for confirming tests from the program.

C. Progress Summary

A prototype system is currently running using real data from the ICU provided on magnetic tape. The program uses a small set of rules (currently around 30) to suggest appropriate time to proceed in the weaning process (i.e. weaning the patient from the ventilator's assistance). It also provides summaries and suggestions about the patient status and recent trends.

A large amount of the work has gone into determining (1) an appropriate representation of knowledge that can deal with the dynamic nature of this problem, and (2) the extent of knowledge needed to develop a satisfactory level of performance in the program. Because this program must run in a near real time environment, a large segment of the design is concerned with rules which can focus quickly on knowledge and processes which are relevant for different patient situations.

E. Funding

Approved by NIH but not yet funded.

II. RESEARCH PLANS

A. Long Range goals and plans

PUFF

Performance Improvement

With the existing PUFF rules, the pulmonary physiologist at PMC is able to process approximately 50% of the patients undergoing the pulmonary function tests. Some of the system interpretations are used with relatively minor stylistic changes in the printed interpretations, while other cases require

important points to be added to the system interpretation. We would like to increase the utility of of PUFF to where it can process 90-95% of the patients. In order to reach this goal the current program must be augmented with rules about:

(1) restrictive lung disease - the current rules do not identify RLD with sufficient accuracy.

(2) modify some of the existing rules on OAD,

(3) add rules to determine patient effort, or lack of effort, during the measurement acquisition,

(4) add rules related to blood gas analysis, and

(5) modify some parts of the PUFF program to increase the efficiency.

Consensus

Physician acceptance of assistance by knowledge-based programs is understandably inhibited by disagreements between physician diagnoses and those produced by the programs. This disagreement reflects a deeper underlying disagreement among the physicians themselves on the rules to be used for diagnosis. A more subtle problem arises when physicians agree on the diagnosis but cannot agree on the supporting evidence or the reasoning which led to the diagnosis. Currently, two pulmonary physiologists are attempting to obtain consensus between themselves and with the current rules in PUFF.

We consider obtaining consensus among physicians an important problem for PUFF's acceptance. At the same time, the process of building consensus about a body of knowledge is an interesting area of research in artificial intelligence. The general question to be answered is: What components of the diagnostic process cause differences in the diagnosis? More specifically, in terms of the knowledge which the physicians bring to bear on the diagnostic process, are there differences in representation? (i.e. do physicians use different forms of knowledge?) Are there differences in the definition? (i.e. do physicians use different models or definitions of disease, manifestations, and diagnosis?) Are there differences in the process? (i.e. do physicians reason differently about the problem?)

A second set of questions are: When designing knowledge-based systems, should it be designed to be modifiable to conform to the user physician's diagnostic process? Or, should it be designed to act to identify and record areas of disagreement among the physicians? Should it warn the physicians, mediate the differences, or merely collect the information?

We would like to spend the next few years answering some of these questions in order to understand the problem of consensus building among physicians.

VM

The long range goal of the VM project is to develop and evaluate an extensive rule base sufficient to improve patient care in the ICU and augment the effectiveness of the current ICU monitoring system. A large amount of effort will be expended in creating a knowledge base capable of handling the various unexpected events which may occur in the Intensive Care Unit to critically ill patients. The knowledge base must also encompass decisions for selection of ventilatory assistance equipment and other important clinical decisions connected with recognition of the patient situation and prognosis.

To insure acceptance by physicians, a careful evaluation of the correctness of the advice of the program against a set of prospective cases will be carried out. A large amount of patient data have already been collected for this evaluation. An experimental period of use in the ICU by clinicians associated with our project is projected before the end of 1980.

The VM program embodies new techniques for knowledge-based programs capable of handling problems dealing with series of interpretations under real time output requirements. The program design should also provide a basis for other medical programs which can handle patient data which change over time, not necessarily in the context of the ICU. We intend the design of the VM program to be independent of the knowledge utilized. The characterization of similar domains to which this new technology can be applied will be an on-going goal of this research team.

III. INTERACTIONS WITH THE SUMEX-AIM RESOURCE

A. Collaborations and medical use of programs via SUMEX

The PUFF/VM project requires very close collaboration between investigators at two institutions separated by fifty miles. This kind of collaboration, in which program development and testing proceeds concurrently on the same application system, requires a network facility for sharing of code, data and ideas. SUMEX has been used at PMC for running programs developed concurrently by Stanford and PMC staff, and data has been taken from the PMC computer system and transferred to SUMEX on magnetic tape for program development and testing.

B. Sharing and interactions with other SUMEX-AIM projects

We have participated in the AIM workshop and had very fruitful interaction with a number of other SUMEX users, directly influencing our perception of important problems and potentially appropriate solutions. Personal contacts at other conferences, at Stanford AI weekly meetings, and at PMC with visiting members of the AIM community, have also been very helpful in keeping abreast of the current thinking of other members of the AI community and with members of the medical community interested in computer based physiological analysis and diagnosis. Specifically, there is the closest possible collaboration with researchers on the MYCIN, MOLGEN and DENDRAL projects, who share common space, common techniques, and common attitudes.